# eCollaboration in Learning, Teaching and Research

## Literature Review Report

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## Overview

This paper presents a literature review of studies of academic collaborations and e-collaborations conducted within the framework of a project that aims to develop the capability of staff in the tertiary sector to set up and carry out effective remote collaborations as part of their teaching or research activities. The development component of the project will involve the creation of a *Guide for eCollaboration in Learning, Teaching and Research* to help tertiary teachers and researchers select appropriate ICT tools and technologies for remote collaborations.

The paper reviews issues related to academic collaborations and e-collaborations pertinent to the development of our understanding of the nature of collaborative activities, especially those involving remote participation. It presents an overview of different types of collaborations in research, teaching and learning, and identifies common tasks, activities and functions associated with remote collaborations. The role of ICT technologies in supporting e-collaborations is also considered. The focus of this review is, in particular, on identifying the kinds of processes that take place in successful e-collaborations and the kinds of technologies that are able to support these processes.

Different collaborative projects, of course, will be based on different scenarios and, depending on the field of study, will require different discipline-specific collaborative functionalities. The goal of this project is not to cover all these diverse disciplinary scenarios and principles, but to identify some core common requirements, functions, and principles of academic collaborations, pertinent to a wide range of collaborative enterprises.

A number of the reviewed publications underscore that the process of collaboration can be substantially improved by training. It is planned, therefore, that professional development workshops will be offered on completion of this project to assist teachers and researchers in applying the Guide in the context of their discipline and gaining skills in using the suggested eTools.

The review shows that, although there are important differences between the culture and goals of e-collaborations in research and in teaching and learning identified in the literature, there are also important lesson to learn from research into e-collaboration practices in both of these two fields. Furthermore, both e-research and e-learning collaborations could benefit from studying ways in which distributed communities that share a common interest or practice function in Cyberspace.

Although the review highlights the complexity of the collaborative enterprise, in particular when it takes place remotely, there is a clear consensus in the literature that collaborative activity, both in research and in teaching and learning, holds significant benefits and will continue to grow. The literature suggests that in undertaking e-collaborations it is important to consider such parameters as the *purpose of collaboration*, *field/s of study*, *participants*, *location*, *duration* and *scale*. The processes and functions associated with collaborations can be roughly grouped into 1) *coordination, administration, project management, leadership*; 2) *production (creation and sharing new knowledge and understanding)*; 3) *content and data management*; and 4) *communication and interaction*.

Accordingly, environments and tools developed or selected for collaborations need to be able to support these processes and functions. This does not imply linear one-to-one tool-function relationships, however, since one tool may be used in different ways to support a range of functions, and vice versa, one process or function may require the use of a number of individual tools.

This paper presents results of a literature review on the topic of e-collaboration in learning/teaching and research. The following questions are considered:

*1. What are the kinds of collaborations that take place in academic contexts?*
*2. What are the similarities and differences between research and teaching/learning collaborations?*
*3. What are the mechanics of academic collaborations?*
*4. What are the critical success factors of academic collaborations?*
*4. How can use of technology support and facilitate e-collaborations?*

# I. Introduction

## *1.1 Academic collaborations*

A number of authors have suggested that academic practices in general, and research practices in particular, have become more collaborative in their nature over time, with collaborators often not sharing the same physical space but rather working in geographically distributed and culturally diverse environments. This trend is shown, for example, in the study by Lariviere (2006) of the collaboration of Canadian researchers in natural and physical sciences, engineering, social sciences and humanities, and in the study by Acedo, Barroso, Casanueva, & Galán (2006) that focused on co-authorship in management and organisational studies.

Melin (2000, p.34) suggests that benefits resulting from collaboration in research include an increased level of knowledge and expertise, higher quality of research, and the possibility of more collaborative work in the future. Other advantages of collaboration in research are higher motivation, potentially higher efficiency and effectiveness, greater productivity, a higher quality of output due to peer reviewing of co-authored work (Katz & Martin, 1997; Duque, Ynalvez, Sooryamoorthy, Mbatia, Dzorgbo, & Shrum, 2005). Borgman (2006, p. 370) points out that research collaborations frequently are based on sharing expensive instruments or resources (see also Olson & Olson, 2000; Finholt, 2002; Sonnenwald, 2007). Furthermore, there are situations when it is impossible to reach the objective without collaboration, for example, in medical collaborations or scientific collaborations, when the required knowledge spans subfields within a discipline or even needs to be drawn from a number of disciplines (to develop a theory or hypothesis, implement and test it, analyse and publish results).

In teaching and learning, the important role of collaboration is acknowledged and discussed in a number of key publications in the field of Higher Education (such as Barkley, Cross, and Major, 2005; Johnson & Johnson, 1996; Millis & Cottell, 1998; Springer, Stanne, & Donovan, 1999). Research findings demonstrate that collaboration promotes and improves learning, and is an important factor in academic achievement, personal development and student satisfaction. O'Donnell, Hmelo-Silver, and Erkens (2006) argue that collaboration among students promotes higher-level learning outcomes, through the development of argumentation skills. Encouraging active learning, cooperation and collaboration among students are also among the seminal *Seven Principles for Good Practice in Undergraduate Education* (Chickering & Gamson, 1987). Furthermore, team work has been identified as one of the core transferable skills valued by employers in the workplace in a recent Graduate Careers Australia's (GCA) survey of employers in Australia and New Zealand (2006).

Latucca and Creamer (2005, p. 9) argue that research into collaborations is an important direction of teaching and learning research:

> As calls for both collaboration (Austin, 2003; Brady, 1999; Rice, 1996) and interdisciplinarity (Boyer, 1990; Hackett, 2000; Rhoten, 2003) increase in colleges, universities, and the workplace, those who support, practice, and study faculty work need greater understanding of the nature and conduct of collaborative interdisciplinary work.

It is worth keeping in mind, however, that collaboration is not always more efficient than working alone, and "sometimes it may even be less productive" (Toomela, 2007, p.199). For example, studies show that brainstorming in a group turns out to be less productive for creating new ideas than working alone. In addition, some people can have a tendency to contribute less when working in a group if individual contribution is not monitored. Social pressure to reach a consensus, sometimes referred to as *groupthink,* may also "lead to biases and blindness to discomforting evidence", and group members' behaviour can be driven by the desire to avoid disapproval (*conformity pressure*) (Toomela, 2007, p. 200). Furthermore, cultural differences may result in inefficiencies.

### *1.2 About collaboration*

So what do we mean by collaboration? Hara (2003, p. 953) summarises collaboration as "working together for a common goal and sharing of knowledge". Similarly, Weiseith, Munkvold, Tvedte, and Larsen (2006, p. 40) suggest that "collaboration takes place when two or more people communicate and interact to reach a goal". Creamer and Lattuca (2005) underscore the *social inquiry* aspect of collaboration, suggesting that collaboration promotes *learning*. In describing collaboration as *social* practice they emphasise the role of interaction and building relationships. *Inquiry* in this context signifies "scientific and artistic explorations that advance knowledge and the co-construction of knowledge and learning" (Creamer and Lattuca, 2005, p. 5). In the context of learning, Oliver, Herrington, and Reeves (2007, p. 2) describe collaboration as "interactions that are interdependent and actually promote the kinds of joint contributions of students that enable outcomes to exceed what might normally be achieved by individual activity".

Both e-research and e-learning are often associated with some form of collaboration (also referred to as *e-collaboration*). Borgman (2006) suggests that e-research can facilitate collaboration through distributed access to content, tools, and services. Kock (2007) defines e-collaboration as "collaboration using electronic technologies among different individuals whose goal is to accomplish a common task" (p. 4). Kock (2007, pp. 5–6) also sets out six key conceptual elements of e-collaboration: the collaborative task; the e-collaboration technology; the individuals involved in the collaborative task; the mental schemas possessed by the individuals; the physical environment surrounding the individuals, and the social environment surrounding the individuals. E-collaboration has also been studied in industry, where "the term e-collaboration is increasingly being used … to denote collaboration activities supported by some form of ICT" (Weiseith et al., 2006, p. 239).

As far as learning is concerned, according to Oliver et al. (2007, p. 2) a number of studies (Gabriel, 2004; Goodsell, Maher, & Tinto, 1992; Roberts, 2004; Swan & Shea, 2005; Slavin, 1990) indicate that "the steadily growing numbers of students enrolled in online courses are increasingly being encouraged to work collaboratively with their peers and others as an integral part of the online learning experience." On the other hand, they also admit that "… many academic staff teaching online are either unaware of the benefits of online communities of learners or do not appreciate the potential of such virtual communities for enhancing learning (Liu, Bonk, & Lee, 2007; Zhang & Walls, 2006)".

Cross-institutional learning collaborations are also becoming more realistic due to advances in Internet technologies. Creanor and Littlejohn (2000), for example, describe cross-institutional collaboration in information and communication technology staff development by two universities in

Scotland (the University of Strathclyde and Glasgow Caledonian University). Other examples of cross-institutional student online collaborations include South African universities developing linkages with partners in the United States (Cogburn & Levinson, 2003; also see Shrum, Chompalov, & Genuth, 2001) and Australia, Canada and Sweden (Larsson, Boud, Dahlgren, Walters, & Sork, 2005).

Another new form of academic collaboration is the University Consortia – the establishment of academic certificate and degree programmes that are offered by multiple universities. Open Universities Australia (OUA), for example, offers its degrees from a number of Australian partner universities by distance study, with an increasing number of courses being offered online. Another example is an international consortium - Universitas 21. U21's partner universities offer a Certificate in Global Issues where courses are taught online as well as via student exchange (http://www.universitas21.com/globalissues.html). U21 has also developed an online graduate school that awards MBAs and other qualifications in the areas of business management and information technology (http://www.u21global.edu.sg; http://www.universitas21.com/global/globalabout.html).

### *1.3 Teaching vs. research collaborations*

A scan of the literature on collaboration reveals a number of differences between learning/teaching and research collaborations. Learning collaborations tend to be more process focused (e.g., creating a learning community, improving the quality of learning, creating opportunities for deep learning), while research collaborations are more product oriented (e.g., research projects that develop or verify a hypothesis, or aim to produce publications).

Borgman (2006) analysed the use of scientific research data from two large scale collaborative research projects - the Alexandria Digital Earth Prototype Project (ADEPT) and the Center for Embedded Networked Sensing (CENS) project - in teaching. Her results show that "faculty members were more interested in tools to manage their own research data than in tools to facilitate teaching. They also were more reflective about their research than teaching activities" (Borgman, 2006, p. 259).

In addition, Borgman (2006, p. 361) points out that "scientists who collaborate with each other tend to have similar disciplinary knowledge and analytical skills. Such similarities cannot be assumed when the same scientific data are shared with teachers and students (Enyedy, 2003)." She also remarks that scientists and students analyse data for different purposes, and have different levels of skills and understanding about working with scientific data and about using data for research purposes. Borgman suggests that "scientists' primary goal is the production of knowledge, while students' primary goal is to learn the concepts and tools of science" (ibid).

Comparing teaching and research, Borgman (2006, p. 366) argues that research is a collaborative activity in most scientific fields, while teaching is usually a solo activity, and that these differences appear to influence incentives to use e-learning and e-research technologies (see also Borgman, 2004). However, Bos and Zimmerman (2007) point out that there are some important distinctions between scientists working together in one-to-one informal collaborative settings and large scale distributed computer supported collaborative projects and programmes, with the former being a traditional well-established way of collaboration in sciences and the latter presenting a much greater challenge.

Research also suggests that "the collaborative activities in the core group (i.e., a group "organized around a thematic research line") as well as in the national and international level are strongly aimed at research" (Akkerman, 2006, p. 30), even though "at the core group level, teaching also motivates academics to work together". Akkerman's research shows that "most academic work within the particular university is focused on teaching, whereas collaborative activities of academics outside the university are focused on research and sharing expertise" (ibid).

In spite of these differences, advances in e-research collaboration can, nevertheless, also benefit e-learning. Because e-research is collaborative in its nature and is leading the way in e-collaboration, learning and teaching collaborations can learn from best practice in e-research. In addition, e-learning can benefit from data and equipment sharing set up originally for e-research purposes. Borgman (2006) suggests that one of the key drivers of e-research in sciences is the phenomenon referred to as the "data deluge" (Hey & Trefethen, 2003), and that "once these data are captured and curated, they can be shared over distributed networks" (p. 360). This means that these same data can be made available for other purposes, such as e-learning. This would need to be accompanied, however, by building teachers' and students' capabilities to work with scientific data. Furthermore, different meta-data structure (models) would need to be used to describe scientific data when they are used for research and teaching/learning (ibid, p. 374). More user-friendly data formats might also need to be developed to make them suitable for less experienced researchers, teachers and students.

### *1.4 Present research*

Assuming collaboration is the desired or necessary reality either in a research or learning/teaching environment, the focus of the present research is on establishing *how* academic collaboration may best be conducted in distributed environments, i.e., on identifying the *mechanics* and *components* of effective academic collaborations, as well as on distilling the *functionalities* (*range of operations*) that are involved in successful e-collaborations. Once identified, the goal is to map these functionalities across to the types of tool or environment that would best support these functionalities.

The literature on collaboration indicates that these questions are not entirely new. Bos and Zimmerman (2007), for example, report on the results of their study of large-scale collaborative projects in science (*collaboratories*). One of the key aims of this project was to "offer advice to collaboratory participants and to funding agencies about how to design and construct successful collaboratories" (ibid, p. 654). Previously, research has also been done on matching technology to various types of tasks (Bafoutsou & Mentzas, 2002; Wenger, 2001). Comparisons between research and teaching collaborations have also been made in the past (Borgman, 2006).

Building on this prior research, the aim is to provide further insights into *academic* collaborations, with a particular goal of developing the capability of staff in the tertiary sector to set up and carry out effective remote collaborations as part of their teaching or research activities. The development component of the project will involve the creation of a *Guide for eCollaboration in Learning, Teaching and Research* to help tertiary teachers and researchers select appropriate ICT tools and technologies for remote collaborations. It is also planned that professional development workshops will be offered on completion of this project to assist teachers and researchers in applying the Guide in the context of their discipline and gaining skills in using the suggested eTools.

Different collaborative projects, of course, will be based on different scenarios and, depending on the field of study, will require different discipline-specific collaborative functionalities. The goal of this project is not to cover all these idiosyncratic disciplinary collaborative scenarios and principles, but to identify some core common requirements, functions, and principles of academic collaborations, pertinent to a wide range of collaborative enterprises.

### *1.5 Types of collaborations*

Even a cursory scan of literature on collaboration indicates that there are many taxonomies for classifying collaborations. One approach is to classify types of collaborative activity based on the *types of participants* (Rich, Robinson, & Bednarz, 2000; Bos and Zimmerman, 2007). Rich et al. (2000, pp. 264–265) introduce five broad categories of educational collaboration: *interactions between students, interactions between staff, collaborative development of teaching resources, databases and information centres, and joint delivery of courses and programmes*. Another taxonomy of collaborations based on types of participants was suggested by Thagard (1997, pp. 245–246), who distinguishes between *employer/employee; teacher/apprentice; peer-similar* and *peer-different* collaborations. In addition, Larson (2003, p. 267) identifies a number of examples of collaborative research partnerships that have taken place between *academics* and the *community*.

Collaborations have also been described in terms of the *location* of participants and *institutional structures*. Akkerman (2006, p. 27), for example, suggests five levels of collaborative activity: *the core group level, department level, faculty level, national level and international level*.

Distinctions are also made in the literature between *formal* and *informal* collaboration, as well as between *direct* and *indirect* (or serial) collaborations (Borgman, 2006, p. 359). Direct collaborations refer to scenarios in which participants work together on research projects, while in indirect collaborations faculty contribute content to a common pool, such as teaching resources, concepts and relationships, or research data. Finally, the *scale* of collaborations has an impact on collaborative processes and required functionalities (Weiseth et al., 2006), where "examples of different levels at which collaboration can occur include individual, project/team, community of interest/practice, organizational, and across enterprises" (p. 247).

For the purposes of this research, we will now take a closer look at the classifications of collaborations and e-collaborations taking place in research and in learning/teaching.

### *1.5.1 Research collaborations*

The most commonly identified aspect of research collaboration is the *co-authorship* of papers and manuscripts for publication (Acedo et al., 2006, pp. 957–958). Collaborative writing (Noel & Robert, 2004, p. 67) strategies include *single writer* (with others playing different roles); *separate writers* (writers working on different parts); *joint writing* (close synchronous collaboration); and *scribe* (one document writer basing text on group discussions). Other types of research collaborations include *joint data collection* and *joint use of technology*, especially in terms of expensive equipment (for example, telescopes for astronomers) (Laband & Tollison, 2000, p. 632). Collaboration can also involve carrying out *complex research projects*, *sharing information*, and *learning about other disciplines* and different approaches (Creamer & Lattuca, 2005, pp. 3–8).

New forms of environment for e-collaboration are emerging, such as *Virtual Research Environments* (VREs) in the UK (De Roure & Goble, 2007; Fraser, 2005; Wilson, Rimpiläinen, Skinner, Cassidy, Christie, Coutts, & Sinclair, 2007; Wilson, Christie, Cassidy, Coutts, Skinner, Rimpiläinen, & Sinclair, 2008) or *collaboratories*, in the US (see more on *collaboratories* below). VREs are essentially a continuation of the development of e-science, which originally aimed at providing "grid-based distributed computing for scientists with huge amount of data" (Fraser, 2005). However, the domain of VRE is broader than that of e-science and comprises the "development of online tools, content and middleware within a coherent framework for all disciplines and all types of research" (ibid). Fraser points out that, if a view of VREs as infrastructure or framework is adopted, then the emphasis is on the "architecture and standards rather than specific applications" (ibid). The primary goal of VRE is to support research, assuming that in today's world research is conducted in a way that is distributed and heterogeneous, and that a small team is considered to be a basic research unit (rather than an individual researcher). In addition, such environments promote the diminishing of the boundaries between scientific work and scientific communication. Fraser also underscores the importance of integrating VREs with existing digital research infrastructure and policies, both at the institutional and national levels. Even though originally developed as environments that support e-science, current advances in the area of VREs are informed by methodologies and research interests of social sciences, and future developments are likely to be influenced by those of arts and humanities (for example, http://www.digitalhumanities.org/ the Alliance of Digital Humanities (ADHO); or http://digitalhumanities.pbwiki.com/ the Digital Humanities Wiki).

In fact, it has been argued that, due to the increased scope that includes social sciences and humanities, the term *e-science* should be replaced by the term *e-research*, where e-research facilitates the development of new forms of research practice across a wide range of disciplines with methodological concerned being the main driver of innovation (and not technological concerns) (Jirotka, Procter, Rodden & Bowker, 2006). Some of the key themes in e-research identified in a series of workshops funded through the UK e-Science Programme are: (1) "fostering and enhancing globally distributed research communities"; (2) issues associated with trust, both in technologies that are increasingly relying on automated system and in "collaborators, their processes, knowledge, skills and intentions"; (3) new forms of knowledge creation, sharing and re-use, including knowledge life cycles, and representation of knowledge and expertise (especially when "shared among large, interdisciplinary and distributed research teams"); and (4) "the design and evaluation of e-Research infrastructure and tools" in view to support and "promote user centred approaches which also scale to the large and distributed user groups" (ibid, p. 252).

As mentioned above, *collaboratory* is another term for e-collaboration environments in science, originating in the US. Collaboratories, first conceptualised by Wulf (1989, 1993), are large-scale computer supported collaborative environments. A five-year (2002–2007) Science of Collaboratories (SOC) project funded by the US National Science Foundation (Bos & Zimmerman, 2007) developed a seven-category *taxonomy of collaboratory types*, which identified key practices, technologies and organizational structures for each collaboratory type (see Table 1).

***Table 1.*** *Taxonomy of collaboratory types (Bos & Zimmerman, 2007, pp. 659-67)*

| Functions / Examples | Technology issues | Organisational issues |
|---|---|---|
| **Type 1: Shared Instruments**<br>**Purpose:** increase access to scientific instruments | | |
| Provide remote access to expensive instruments;<br>Supplemented with chat, video-conferencing, electronic lab notebooks, other communication tools.<br>*Example*:<br>The Keck Telescopes in Hawaii (Kibrick, Conrad, & Perala, 1998). | Pushing the envelope of synchronous communications and remote-access technology;<br>Managing large instrument output databases;<br>Providing security around data; | Allocating access;<br>Providing technical support; |
| **Type 2: Community Data Systems**<br>**Purpose:** creation and maintenance of information resources (semi-public and of wide interest). | | |
| Creation of large scale datasets;<br>Creation of standards and protocols.<br>*Examples*:<br>- The Protein Databank – worldwide repository for the processing and distribution of 3-D structure data of large molecules of proteins and nucleic acids (Berman, Bourne, and Westbrook, 2004).<br>- The Visible Human (Ackerman, 2002) | Data standardization;<br>Modelling and visualisation techniques; | Motivating contributions;<br>Developing/deploying large-scale decision-making methods; |
| **Type 3: Open Community Contribution Systems**<br>**Purpose:** open projects (often including members of general public) focusing on a common research problem | | |
| Collect and aggregate data;<br>Make aggregated data freely available to commercial and non-commercial users.<br>*Examples*:<br>- Open Mind project – online system of collecting common sense judgements (aggregated data are made available to artificial intelligence projects)<br>- NASA's Clockworkers project<br>- Wikipedia | Creating a system that operates across platforms and is easy to learn and use;<br>User centred design;<br>Standardised data formatting delivered by simple data entry methods; | Maintaining quality control;<br>Community vetting of data;<br>Volunteer editors;<br>Reaching and motivating contributors; |

| Functions / Examples | Technology issues | Organisational issues |
|---|---|---|
| **Type 4: Virtual Communities of Practice** (Wenger and Lave, 1998)<br>**Purpose:** communication about a shared research area | | |
| Share news of professional interests, advice, techniques, pointers to other resources;<br>(Are NOT focused on undertaking joint projects).<br>*Example*: Ocean.US – meeting place for researcher studying oceans (Hesse, Sproull, Kiesler, and Walsh, 1993) | Using Internet-standard technologies, such as listserv, bulletin boards, accessible web technology;<br>Main issue – *usability*;<br>Emphasising asynchronous or synchronous technologies; | Maintaining energy and participation rates with a shifting set of participants;<br>Web site management; |
| **Type 5: Virtual Learning Communities**<br>**Purpose:** increase the knowledge of participants (rather than focused on original research) | | |
| Educational projects;<br>Formal education through a degree granting institution;<br>In-service training;<br>Professional development.<br>*Example*: The Ecological Circuitry Collaboratory – investigators and their students in ecological sciences. Activities include short courses and exchange of ideas and information between students and investigators. | Overcoming disparity in technology infrastructure between educational institutions;<br>Specialised e-learning software;<br>One-to-many broadcasts;<br>Supporting small groups working in parallel;<br>Software compatibility with different platforms (Windows, Macs, Linux); | Leading teams' integration and synthesis activities;<br>Coordinating distributed activities;<br>Supporting faculty mentors;<br>Aligning educational goals and assessment, meeting the needs of learners from multiple sites; |
| **Type 6: Distributed Research Centres**<br>**Purpose:** aggregate scientific talent, effort, and resources beyond the level of individual researchers | | |
| Like a university research centre but at a distance;<br>Large collaborative programmes.<br>*Example*: Inflammation and the Host Response to Injury Programme – involves interdisciplinary network of investigators from U.S. academic research centres. | Standardization of data;<br>Providing long-distance technological support;<br>Technologies for workplace awareness, such as Instant Messaging to indicate when collaborators are able to engage in quick consultation and informal chat; | All previously mentioned issues;<br>Gaining and maintaining participation among diverse contributors;<br>Standardizing protocols over distance;<br>Facilitating distributed decision making;<br>Providing long-distance administrative support;<br>Settling questions of cross-institutional intellectual property;<br>Careers of young scientists; |
| **Type 7: Community Infrastructure Projects**<br>**Purpose:** develop infrastructure for work in a particular domain | | |
| Infrastructure – common resources that facilitate science, such as software tools, standardized protocols, new types of scientific instruments, and educational methods.<br>Bring together scientists from multiple specialties, private sector contributors, funding officers, and computer scientists.<br>*Example*: The GriPhyN (Grid Physics Network) – implement Petabyte-scale computational environment for data-intensive science. | Developing new field standards for data and data collection protocols;<br>Managing very large datasets;<br>Data provenance – keeping track of editing and transformations on datasets; | Negotiating of goals among disciplinary partners in interdisciplinary projects, and between computer scientists and disciplinary experts;<br>Choice between academic and public sector managers;<br>Careers of young scientists; |

The seven categories identified in Bos and Zimmerman's taxonomy emerged as a result of analysing a large dataset, rather than defined a-priori at the outset of the project. To clarify the distinctions between these classes of collaboration, Bos and Zimmerman map them across two dimensions of activities and resources (see Table 2). The complexity (and consequently demands in terms of management) and risks (such as sustainability) increase in this table from top left to bottom right.

***Table 2:*** *Collaboratory types by resource and activity (after Bos and Zimmerman, 2007, p. 668)*

| **Resource** / **Activity** | **Tools (instruments)** | **Information (data)** | **Knowledge (new findings)** |
|---|---|---|---|
| **Aggregating** across distance (loose coupling, often asynchronously) | *Shared Instrument* | *Community Data System* | *Virtual Learning Community, Virtual Community of Practice* |
| **Co-creating** across distance (requires tighter coupling, often synchronously) | *Infrastructure* | *Open Community Contribution System* | *Distributed Research Centre* |

*1.5.2 Learning collaborations*

Johnson, Johnson and Smith (1991; 1998) distinguish types of student collaborative groups on the basis of *duration* and *purpose*. They distinguish between "formal learning groups" that last from one class to several weeks and are set up to complete a task or assignment. The purpose of these groups is to accomplish a shared goal, capitalize on different talents and to maximise the learning of everyone in the group. The second type, short-term "informal learning groups" last for only one discussion or one class period; the major purpose of forming these groups is to ensure active learning. Finally, "base groups" are heterogeneous "long-term groups with a stable membership, more like learning communities; their purpose is to provide support and encouragement and to help students feel connected to a community of learners" (Barkley et al., 2005, p. 8). Development of virtual learning communities and learner communities of inquiry are considered to be worthwhile long-term goals of educational collaborations.

Learning collaborations that are based on examples of real-life tasks or scenarios may reflect, on a smaller scale, some of the research and industry collaborations, for example, collaborative writing/editing/publishing, team research projects, team development projects, collaborative enquiry project, team presentations, etc. (O'Donnel, et al., 2006). However, the main goals of learning collaborations are promoting higher-level learning outcomes through student knowledge construction, and improving the quality of student learning experiences.

*1.5.3 Teaching collaborations*

Teaching collaborations appear to focus on (1) collaborative *development* of teaching resources, and *sharing* research data and resources for teaching purposes, (e.g., using databases and information centres) (Borgman, 2006) and (2) joint *delivery* of courses and programmes, with contributions from experts with different knowledge bases and perspectives (Creamer & Lattuca, 2005; Larsson et al., 2005; McMahon, Gantz, & Greenberg, 1995).

*1.5.4 Groups and communities of collaborators*

In the networked world, the nature of collaborations is affected by the groups' understanding of the goals and desired outcomes of their collaborations. This can vary from highly goal-driven research or industry collaborations, where deadlines and outcomes are often set in advance by (or in negotiation with) some external bodies (e.g., funding agencies), to more open-ended ongoing collaborations, where knowledge sharing, community building and socialisation of new members into the culture and work ethics of a particular community are valid goals in their own right.

*Communities of Practice* (CoP) are an example of the latter. According to one of the founders of the term, Etienne Wenger, CoP are *"groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly"* (http://www.ewenger.com/theory/). The other types of networked communities are the so-called "innovative knowledge communities" and "communities of inquiry". Wilson, et al. (2007, p. 292), referring to Hakkarainen, Palonen, Paavola, & Lehtinen (2004), argue that "in contrast to communities of practice, innovative knowledge communities are more focused on *knowledge creation* as opposed to socialisation and maintenance". Wilson et al. (2007) carry on to suggest that the aim of communities of inquiry is to "create a deeper, more rounded understanding, new knowledge and practical solutions to the issues being considered" (p. 292). These communities can be composed of individuals who do not necessarily share the same background or view, but who are "committed to working together to explore agreed issues and questions" (ibid). For example, in the context of educational research, this model can promote collaboration between research, policy and practice communities, as demonstrated in case studies based on the AERS Learners, Learning and Teaching Network Project described in Wilson et al. (2008). Another classification of virtual communities has been offered, based on the degree of cohesion and intentionality, by Henri and Pudelko (2003), who distinguished communities of interest, goals, learners and practice.

Functionalities, processes and tools associated with *communities of practice* and *communities of inquiry* are discussed further in sections *2.3* and *2.4.1*, respectively.

## II. The Mechanics of Collaboration

A disclaimer needs to be made from the outset that research projects in different scientific fields need highly specialised instruments and technologies (e.g., telescopes, microscopes, modelling and visualisation technologies). In addition, for large-scale research projects task based classifications may not be all that useful because these projects perform a whole array of tasks throughout their life cycle which require numerous tools and technologies to support them (Bos & Zimmerman, 2007). Nevertheless, there are generic processes and sub-processes associated with many collaborative activities or project, such as *negotiation*, *decision-making*, *brainstorming*. Referring to the field of collaborative engineering in distributed environments, for example, research reveals the following common patterns of collaboration: *diverge, clarify, reduce, organize, evaluate,* and *build consensus* (de Vreede, Kolfschoten, & Briggs, 2006).

Fraser (2005) claims that, in order for a virtual research environment to facilitate multidisciplinary research and encourage innovation within a particular discipline, a good understanding of the research life cycle is needed. With a proviso that it is difficult to divide the research process into a number of discrete steps and that this processes is neither simply linear nor cyclical, Fraser (2005, p. 3) proposes five "more general aspects of a research life cycle" in a university context. These include (1) *research administration and project management* that need support in the form of e-administration; (2) *discovery, collection and analysis* that require intelligent searching abilities, virtualisation and visualisation tools and data collection, analysis and storage capabilities, as well as the implementation of agreed standards; (3) *communications* that support group work, including video conferencing, support for collaborative work and information management; (4) *scholarly publishing* including abilities to peer-review papers and create electronic repositories; and (5) strengthening *relationship between the research and teaching environments* by making resources, data and tools of a VRE available in VLEs (virtual learning environments), through applying open standards that enable communication between the two kinds of environment.

In his research on design and evaluation of collaborative systems, Dewan (2001; based on Dewan et al., 1994) identified a number of functions a collaboration system needs to be able to perform. These include *productivity*, *user and data management*, *work and process flow*, *awareness* and *session management* functions. Dewan also proposed supplementing the functional decomposition approach to system design with the study of application-specific and application-independent *collaboration scenarios*, on the one hand, and driving system requirements from some *general principles*, on the other. By general principles, he means "rules regarding design and implementation of a collaboration function that are independent of specific scenarios, models, abstractions, and architectures..." (Dewan, 2001, p. 87)

### *2.1 Classifications of systems and tools supporting collaboration*

Taxonomies of collaborative applications have been developed to reflect various dimensions, including the time (synchronous/asynchronous) and place (co-located/remote) of collaboration, group size (large-small), task type, application functionality and others (Bafoutsou & Mentzas, 2002; deSanctis & Galuppe, 1987). Bafoutsou and Mentzas (2002) also identified a list of most commonly encountered services collaborative systems provide, by reviewing 47 commercially available systems. Based on their most important characteristics, the authors then grouped all services along two dimensions: the level of *functionality concerning collaboration* (bulletin boards, discussions, e-mails, e-mail notifications, online paging/messaging, chat, whiteboard, audio/video conferencing, task list, contact management, screen sharing, survey/polling, meeting minutes/records, meeting scheduling tools, presentation capabilities, project management) and *document management capabilities* (file and document sharing, document management, synchronous work on files/documents). Finally, Bafoutsou and Mentzas deduced four categories based on the typical characteristics of each category: (1) group file and document handing; (2) computer conferencing; (3) electronic meeting systems; and (4) electronic workspace (ibid, pp. 291-292).

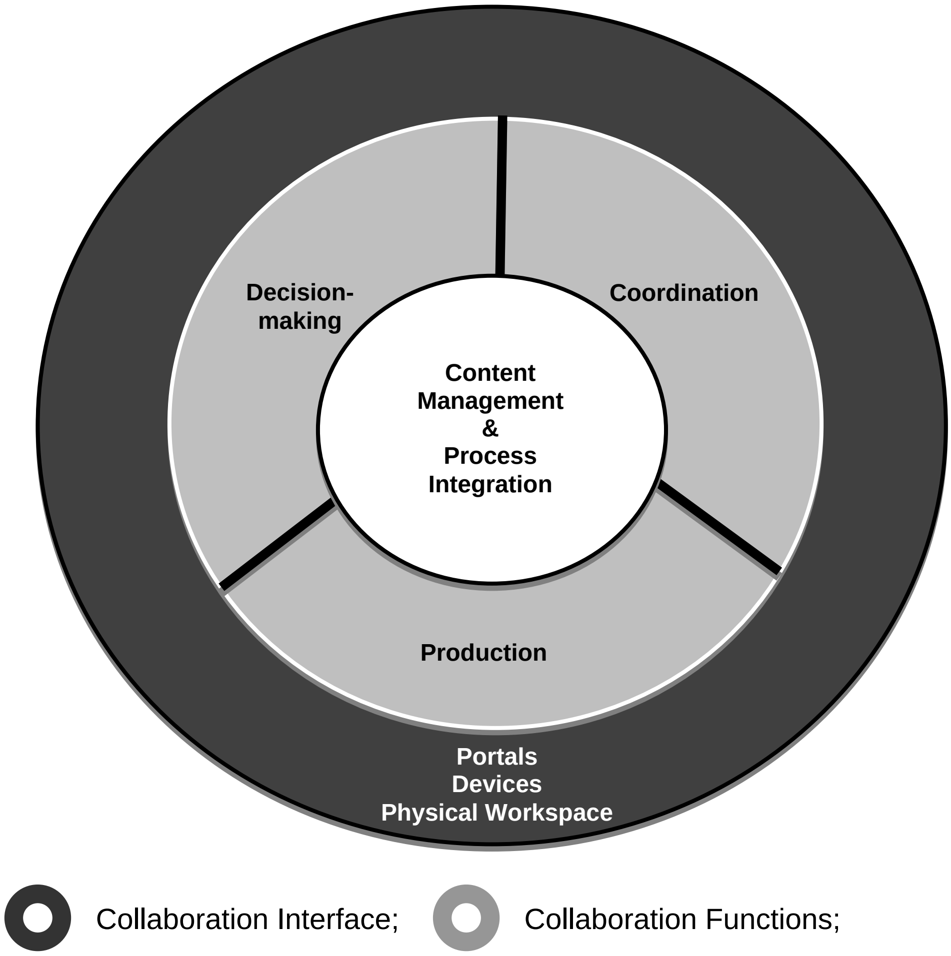
In their later work (Mentzas & Bafoutsou, 2004) suggest that, based on previous research, three core dimensions of e-collaboration emerge: *communication*, *cooperation* and *coordination*. By *communication* the authors mean “explicit interactions between two or more people, either during discussion or during the exchange of electronic messages”, which “do not usually have structure or specific sequence of step” (p. 28). Communication tools include text-base or multimedia synchronous and asynchronous communisation tools, such as e-mail, chat, bulletin board, voice and multimedia conferencing. *Cooperation* refers to working on shared documents and files of various formats. The aim of cooperation is to generate artifacts. Group work is stored in repositories. Cooperation may include implicit interactions through references to a shared artifact. Examples of cooperation tools are whiteboard, file and document sharing, screen sharing and presentation capabilities. Finally, *coordination* “focuses on programming and scheduling of activities performed by the involved actors in a collaboration process” (p. 29). Coordination capabilities are provided by such tools as electronic calendaring, task lists and meeting scheduling tools, and workflow management systems. Interaction is implicit, remote and asynchronous.

### *2.2 Wheel of collaboration tools*

A typology of the capabilities of collaboration tools, the *Wheel of Collaboration Tools (WCT),* developed by Weiseith et al. (2006), deserves special attention because it is aligned with the goals of this research and development project. This typology identifies structural elements of collaborations and functions that support the collaboration process. “Metaphorically, the collaboration interface represents the tire, the collaboration functions are the spokes, and content management and process integration is the hub of the Wheel of Collaboration Tools” (p.243). [Figure 1]

Weiseth et al. (2006, p. 239) suggest that “collaboration process consists of sub-processes, which again are detailed further into collaboration functions”. To analyse collaborations, they define a framework consisting of collaborative *environment*, *process* and *support*. The *environment* includes the nature of the task, the organisational setting, and cultural beliefs. *Collaboration support* consists of *organisational measures, services* and *tools*. “Tools improve the way people collaborate and utilize the potential of digital technologies. A tool represents a combination of *collaboration interface*, *collaboration functions*, *content management* and *process integration*, and should support the preferred *methods* and *communication styles* for the collaboration process” (p. 242). The *collaboration process* is constrained by the pre-existing environment, and also by the support. Weiseth et al. propose that the *collaboration process is “the arena for balancing the business perspective and the technology perspective, i.e. what to do and how to do it”* (p. 241).

***Figure 1.*** *The Wheel of Collaboration Tools (simplified)*

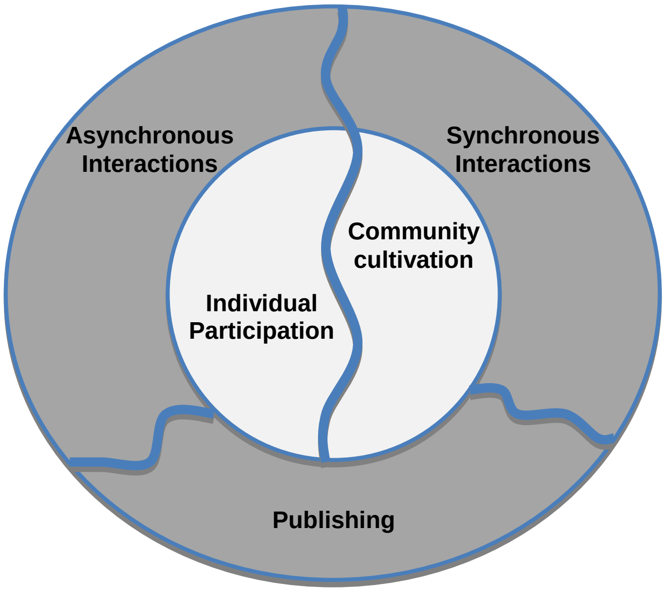



Weiseth et al. (ibid) propose that *collaboration process* consists of three fundamental and interrelated *sub-processes (functions)* through which collaboration takes place: *coordination* (to align independent sub-tasks), *production* (performing core tasks) and *decision-making* (to make choices on task-related issues). Coordination involves managing dependencies by organising the "division of labour into different tasks to be performed", and the "coordination of these tasks to accomplish the overall activity" (p. 242). Coordination is either done by *plan* (including standardisation) or by *feedback* (March and Simon, 1958). The next sub-process of collaboration, production, covers activities and tasks related to creation and sharing of information and knowledge. This includes co-creating activities (e.g., authoring information in a shared environment), aggregating activities (capturing information), and disseminating activities (e.g., distribution and publishing of information through asynchronous or synchronous communication channels; mechanisms for effective search and retrieval). Finally, decision-making sub-processes involve analysing and evaluating alternatives and making a choice. In addition to the three basic collaboration sub-processes, there is the challenge of managing the information dealt with during the sub-processes, i.e., *content management.* Functions associated with content life cycle management are *storing, managing, distribution* and *disposal* of digital content. Furthermore, the functions of coordination, production, decision-making, and content management need to be integrated in a way that assists the transition and flow of process results and context information within and between these sub-processes.

### *2.3 Functionalities for communities of practice*

Wenger, White, Smith, and Rowe (2005) point out that, while in the past taxonomies of collaboration technologies were built along the space and time dimensions (same/different) or functionalities (i.e., what can be done with a tool; e.g., a tool for document management, file sharing, etc.), modern approaches should embrace the complexity of functionalities that cannot be supported by one tool only (e.g., the "emergence of a community perspective" or "the role of community leaders") and acknowledge that "individuals and communities don't necessarily use technologies in consistent or intended manners" (ibid, p. 4). The researchers suggest that activities CoPs are engaging in can be grouped into three broad categories *interacting* (connecting in and across time and space), *publishing* (which requires organizing communal repositories as well as individual access to them) and *tending* (i.e., members need ways to participate personally, as well as cultivate their community). They propose an approach to classifying tools available on the technology market using a diagram representing activities and tensions of a CoP by five regions within a sphere [Figure 2].

***Figure 2**. Landscape of CoP Tools (simplified)*




In the outside band of the sphere, they place three general types of activities: *synchronous interactions*, *asynchronous interactions*, and *publishing*. These activities represent one of the two key tensions of online CoP - the experience of togetherness in the context of separation in time and space. The middle of the sphere is divided into two semi-circles corresponding to two community-building activities: *individual participation* and *community cultivation*. These two activities represent the second key tension of CoP, i.e., the relationship between communities and individuals (Wenger et al., 2005, p.5).

## 2.4 Teaching/Learning collaborations

In the area of teaching and learning it has been argued that significant advantages and opportunities can result from a sense of community (e.g., Oliver et al., 2007), associated with "a feeling of belonging to a group (membership), a feeling of influence within the group, fulfilment of needs and a shared emotional connection with other members." (Oliver et al., 2007, p. 3, based on McMillan & Chavis, 1996).

In the literature on collaborative learning, it has been argued that "a collaborative environment where learners can validate their perspectives through social negotiation and interaction with an authentic task" facilitates constructivist approaches to learning (Edwards, Watson, Farrell, & Nash, 2007, p. 27; Johnson et al., 1991, 1998). Problem-based collaborative learning, for example, is known to help students develop skills and confidence in formulating and solving problems (Smith & Starfield, 1993), in particular in introductory science and engineering courses.

### *2.4.1 Community of Inquiry*

One of the best known forms of online learning collaboration is the *community of inquiry* (e.g., Garrison, 2006). It has been argued (Borgman, 2006, pp. 366-367) that the aim of inquiry learning is "to involve students in scientific practices so that they gain a deeper epistemological understanding of science." This approach challenges the information transaction model of teaching, adopting the "assumption that the goal is to create a community of inquiry where students are fully engaged in collaboratively constructing meaningful and worthwhile knowledge" (Garrison, 2006, p. 25). Note that this approach places knowledge construction at the core of collaborative activity. So even though the production of *new* knowledge remains the prerogative of research (and research collaborations), this teaching/learning approach maintains that deep learning involves active knowledge construction by the learner.

In the context of formal learning (e.g., in tertiary education), the community of inquiry model rests on three pillars: *social presence* (creating personal connections with members of the community), *cognitive presence* (constructing meaning through collaborative inquiry) and *teaching presence* (facilitates constructive, collaborative and sustained learning environment) (Garrison, Anderson, & Archer, 2000). These are the three inseparable elements of constructive-collaborative learning. Garrison (2006) further proposes that there are three key elements of teaching presence that help make the learning experience meaningful and worthwhile: *design of courses, facilitation of discourse* and *direct instruction* (see Table 3).

***Table 3***: *Community of Inquiry (Garrison, 2006, pp. 26–33)*

| **Teaching Presence** | **Social Presence** | **Cognitive Presence** |
|---|---|---|
| ***Design***<br><br>*Goal – create and sustain a sense of community* | **Principle**: *Establish a climate that will create a community of inquiry* (a climate of trust and belonging that supports interaction and questioning).<br><br>- Opportunities for students to interact formally and informally with peers<br>- Opportunities to establish trust and get to know each other | **Principle**: *Establish critical reflection and discourse that will support systematic inquiry*.<br><br>- Design learning activities that help students progress through the phases of inquiry: problem definition → exploration of content and ideas → integrating ideas into a structure or solution → testing the validity or usefulness of the outcomes |
| ***Facilitating Discourse***<br><br>*Goal – sustain social presence while creating cognitive presence* | **Principle**: *Sustain community through expression of group cohesion (collaboration and support)*.<br><br>- Environment supports collaborative and reflective discourse<br>- Teacher provides skilful facilitation<br>- The teacher is present, but is not the centre of discourse<br>- Students develop facilitation skills to engage in collaborative activity | **Principle**: *Encourage and support the progression of enquiry through to resolution*.<br><br>- Students are actively sharing, testing and confirming ideas<br>- Model critical inquiry and sustain cognitive presence<br>- Provide stimulating questions<br>- Keep discussion focused<br>- Identify issues needing clarification<br>- Move discussion forward in a timely manner |
| ***Direct Instruction***<br><br>*Goal – provide academic and pedagogic leadership* | **Principle**: *Evolve collaborative relationships where students are supported in assuming increasing responsibility for their learning*.<br><br>- Teaching presence helps develop and maintain the climate of collaborative learning<br>- Team building activities<br>- Teaching presence helps address and resolve tensions and conflicts | **Principle**: *Ensure that there is resolution and metacognitive development*.<br><br>- Ensure that discourse and collaboration achieve the larger educational goals<br>- Diagnose misconceptions and provide explanations<br>- Time management<br>- Offer expert knowledge to understand nuances of the discipline<br>- Provide a practical inquiry model to develop metacognitive awareness<br>- Contribute ideas and perspectives<br>- Make connections, integrate and summarise ideas before moving on |

Garrison argues that well-designed *team projects* allow students to recognise a need to lead, set goals, plan and manage tasks, assess progress, and adjust strategies. Communication is a critical component of online collaboration, according to Garrison, and must include discourse that is *purposeful*, *threaded* and *reflective* (p. 25). The importance of communication in the academic learning situation is also highlighted by Diana Laurillard (2002) in her conversational framework for the effective use of learning technologies. Laurillard views learning as "a continuing iterative dialogue between teacher and student, which reveals the participants' conceptions, and the variations between them, and these in turn will determine the focus for the further dialogue" (p. 71).

In a face-to-face (f2f) environment, collaborative learning, according to Johnson and Johnson (1996), includes a number of *major types of behaviours,* such as *seeking and receiving help, advice and feedback; exchanging resources and information; sharing knowledge; challenging others' contributions (cognitive conflict leading to negotiation and resolution); as well as monitoring the efforts and contributions of others; and engaging in small group interaction*. The analysis of students' textual online interactions conducted by Curtis and Lawson (2001, p. 26) shows that most of these collaborative learning behaviours were present in the online environment. However, challenging others and offering explanations were absent from the students' textual exchanges, and interactions in the *reflection/monitoring* category were mainly focused on the medium and not on the task progress. On the other hand, *planning activities* were more prominent in the online than in the f2f environment, which could have been due to limitations of asynchronous online interactions. Interestingly, the *construction of knowledge* was not included as one of the core behaviours of f2f learning collaborations by Johnson and Johnson, and nor did it emerge in the analysis of online interactions conducted by Curtis and Lawson, supporting the point made earlier about differences between research and learning collaborations.

### *2.5 Virtual teams*

Collaboration is an important component of the work conducted in *virtual teams* (Tarmizi, Payne, Noteboom, Zhang, Steinhauser, de Vreede, & Zigurs, 2006). Such teams can be formed in research, teaching, learning or industry environments. The collaboration phase in the work of virtual teams, however, does not typically occur at the initial stages, which are primarily about initiation and exploration. In fact, "efforts are needed to move virtual teams from initial or exploration phases to a collaboration phase, and some teams might simply fail to reach the collaboration phase" (ibid, p. 40). When studying collaborations, it is important therefore to pay attention to the time-frame of the collaboration, because it has an impact on the nature of activities in virtual teams.

The development of shared understanding is essential for the success of virtual teams. This can be achieved through *structured deliberations*, *discussions*, *information exchange*, and *guidance by a team leader* that are, in turn, the result of carefully structured team processes and leadership (Tarmizi et al., 2006, p. 41).

## III. Critical Success Factors

Before embarking on collaborative work, be it in teaching/learning or research, it is useful to consider what is already known about factors affecting collaborations. Olson (2008, pp. 1–3) proposes five key components that affect the success of remote collaborations**:** *the nature of the work; the amount of common ground among participants; their readiness to collaborate; their management style and leadership, and technology readiness* (see Appendix 1 for details).

Furthermore, the effectiveness of collaboration is affected by the level of complexity based on team composition, whether it is unidisciplinary, multidisciplinary, interdisciplinary, or transdisciplinary (Toomela, 2007, p. 201). Walsh and Maloney (2007, p. 713) also identify group size, diversity and group cohesion among factors that affect collaboration. Even though interdisciplinary collaborations can be challenging because diversity means less common ground and less trust, which can impede understanding and production of new ideas (Olson, 2008, p.3), when people from diverse discipline and backgrounds work together they are able to engage in more creative activity.

For interdisciplinary collaborations, it has been suggested that critical success factors are related to skills, experiences and attitudes (Maglaughlin & Sonnewald, 2005). Toomela (2007) emphasises a requirement for collaborative teams to be built so that members possess different but complementary knowledge. To manage differences of opinions between collaborators, Creamer (2004, p. 569) recommends to (1) organise groups with comparable levels of expertise; (2) attend to interpersonal dynamics in the group; (3) create a culture where differences of opinion are valuable and open to discussion; (4) establish an expectation that feedback will be provided; and (5) provide opportunities for informal conversation and exchange.

When data sharing is involved, data standards need to be agreed on and archiving procedures need to be put in place. David and Spence (2003) suggest that agreements about sharing data are central to establishing collaborations. Borgman (2006, p. 360) also points out that "sharing data is a core element of scientific collaboration. It is a complex social process involving trust, incentives, disincentives, risks, and intellectual property." On the one hand, scientific inquiry is enhanced and more efficient when data and instruments are shared remotely; on the other hand, large scale projects with multiple participants result in greater coordination overheads. Good management and decision making are needed to address these issues.

In the ADEPT (Alexandria Digital Earth Prototype Project) – a project aimed to make geo-spatial resources intended for research usable in teaching and learning – Borgman (2006, p. 373) noticed that best results were achieved by enabling each instructor to gather his or her own resources into a ''personal digital library", or by creating such libraries for collaborative teams. This enabled faculty members to choose whether they wanted to share their personal digital libraries with others and to make items visible or not visible in the shared collection. This approach addressed issues related to intellectual property rights (especially that of original research data), and enabled faculty members to use their research data for teaching without having to contributing them to a common pool.

In terms of learning collaborations, Oliver et al. (2007, p. 2), based on Dolmans, Wolfhagen, Scherpbier and van der Vleuten (2003), suggest that collaborative learning takes place when the following conditions are met: *students have a common goal*, *share responsibilities*, *are mutually dependent* and *need to reach agreement through open interaction*. When students engage in collaborative online inquiry, Garrison (2006) points out that teaching presence in the form of course design, facilitation of discourse and direct instruction is critical for ensuring the success of the other two essential component of inquiry-based learning: social presence and cognitive presence. Macdonald (2003) highlights the importance of selecting an appropriate model of assessment in collaborative learning and encouraging online participation. In particular, she urges educators to consider both the process and product of collaborative learning. Macdonald (ibid, p. 390) suggests that "[t]he product of online collaborative work need not necessarily be assessed, but if it is this may demand the use of additional skills such as peer review, time management and task negotiation". Macdonald proposes that the transcript of online interactions opens up new avenues for assessing the collaboration processes that is not possible in a f2f situation.

It is important to point out that collaborative approach should not be seen as an optimal approach to all academic work, and that not all types of collaboration are appropriate for all research or learning contexts. Toomela (2007), for example, distinguishes between *unidirectional* or *dialogical* collaborations (p. 202). In *unidirectional* collaborations the goals, questions and the selection of relevant information is done by one person, i.e., there is one person who absorbs knowledge provided by others, and the product of collaboration depends on one person. In dialogical collaborations, team members complement each other, the choices are made by a team as a whole, all members of the team share the common understanding about research questions, selected information, and research methods. The product of such collaboration is collective creation. Toomela (ibid) further argues that knowledge constructed in science can be *elaborative* or *emergent*. By *elaborative* knowledge Toomela means the kind of knowledge constructed to elaborate a theory and involving finding problems, raising questions, formulating hypotheses, while *emergent* knowledge does not offer clear questions to be answered through research (e.g., the creation of novel theories, or generating new ideas). Thus, for building emergent knowledge, only individual or unidirectional collaboration is productive, while dialogical collaboration can hinder or even prevent the construction of this kind of knowledge (p. 198). In fact, Toomela suggests that collaboration is generally more successful where *elaborative* knowledge is involved, as research shows that "when groups and individuals are presented with problems for which there is a precise answer, groups are more likely to arrive at the solution than the average individual" (p. 203).

In teaching, a potential danger of collaborative or team-based approach is the loss of individual autonomy and the imposition of common formats which may work against teaching innovation (Rich et al., 2000). Rich et al. point out that "the emergence of multi-skilled teams, adoption of shared curricula or the use of collaboratively produced resource materials, for some undoubtedly represents a 'cost' of collaboration on teaching innovation, although from another perspective the opportunity for greater reflection on, and wider scrutiny of, teaching may well be seen as a 'benefit'" (Rich et al., 2000, p. 267).

### *3.1 Subject/Discipline Related Factors*

The literature on collaboration reveals that collaborative approaches are more likely to be adopted in the sciences than the humanities. Borden (1992, p. 136) has noted that in the humanities, "collaboration has been more the exception than the rule", and that this is due "to the 'sociology of the humanities': the transmission from faculty to students of values and behaviors whose hold is strong and that overwhelmingly favor the individual effort." Morrison, Dobbie, & McDonald (2003, p. 276) also point out that in the humanities "research remains largely the domain of the individual scholar." Borman's (2006) research shows that even within the same discipline, geography, "psychical geographers were likely to participate in large collaborative projects and their research was more data-driven", while "human geographers tended to work on their own and to write sole-authored scholarly books; their research was more concept driven than data-driven" (p. 264), even though both groups used the same information resources. These differences in collaboration culture are considered to reflect the differences between *high-consensus* or *low-consensus* fields of study (Creamer, 2004, p. 557). High-consensus fields are where there is a consensus about central paradigms, for example, physics. Low-consensus fields do not currently have a consensus about central paradigms (for example, in the humanities). It has been argued that high-consensus fields are likely to have higher levels of collaboration and that differences of opinion are more likely in low-consensus fields. In addition, there is some evidence that collaboration is more effective in fields where there are clearly formulated problems and questions, such as applied science, as opposed to basic science (Toomela, 2007, p. 203).

### *3.2 e-Collaboration*

These disciplinary trends can also be observed in e-research. Borgman's (2006) findings show that "research specialties that are more collaborative and make more use of instrumentation are more likely to use e-Research technologies" (p. 365). In addition to more general factors affecting the success of collaborative enterprises in learning, teaching and research, e-collaborations have a whole raft of additional challenges. Some of these challenges are caused by the lack of visual contact, and, consequently, absence of such socio-linguistic features as the tone, facial expression and body language of the participants of interactions, which are very important for effective communication. Other challenges are associated with the use of new technologies. It has been pointed out that participants who are new to distributed collaborations need training and help in developing skills and understanding to adapt to the new social and technological settings of e-collaborations (e.g., Bliesener, 2006).

Despite technological advances, it has been argued that *distance* remains a factor that can inhibit collaboration (Olson & Olson, 2000; Walsh & Maloney, 2007) and that stress can be a problem for online collaborators (Allan & Lawless, 2003). Research collaborations over distance are complicated with the added challenges of coordination and trust building. Distance may foster misunderstanding and inhibit communication of tacit knowledge and transactive knowledge, i.e., knowledge of what colleagues know (Bos and Zimmerman, 2007, p. 654). Olson's summary of literature on challenges facing remote scientific collaboration indicates that "[f]or one, distance threatens context and common ground (Cramton, 2001). Second, trust is more difficult to establish and maintain when collaborators are separated from each other (Shrum et al., 2001; Kramer & Tyler, 1995). Third, poorly designed incentive systems can inhibit collaborations and prevent adoption of new collaboration technology (Orlikowski, 1992; Grudin, 1988). Finally, organizational structures and governance systems, along with the nature of the work, can either contribute to or inhibit collaboration (Larson, et al., 2002; Mazur & Boyko, 1981; Hesse et al., 1993, Sonnenwald, 2007)". The costs of distributed collaborations are also associated with additional bureaucracy, infrastructure and technology (Larsson, 2005; Rich et al, 2000).

In the learning context, online group work may cause stress if members of a group are required to meet deadlines for collaborative/cooperative activities where the group members are dependent on each other to do well, but do not know each other well and have not had the opportunity to build up a relationship (Allan and Lawless, 2003). While Allan and Lawless focus on students and the pressure of deadlines for group assignments, it is not difficult to envisage a similar scenario for research collaborators, for example, when working to a deadline for an article or when reporting to a funding agency.

## IV. Use of Technology

Technology is increasingly used as a core vehicle for distributed collaborations in learning, teaching and research. In e-collaboration, the use of technology is both an enabler and a challenge.

### *4.1 Technology as an enabler of collaboration*

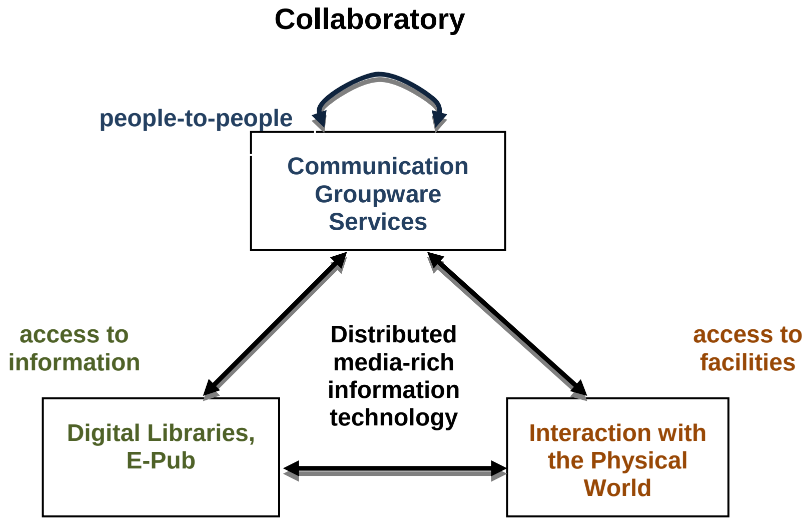
Virtual teams of both students and researchers have a high degree of reliance on information and communication technology (Tarmizi et al., 2006). Today learning collaborations between students have a tendency of moving online, with discussion forums, online group assignments and virtual team projects being part of the modern academic study environment (Oliver et al., 2007). Wang (2007, pp. 282–283) has argued that the Internet has strong potential for promoting collaboration and that the World Wide Web can "be a place for faculty to invite students to collaborate and innovate." Garrison (2006) suggests that online learning has an advantage compared to f2f environment in supporting collaboration and creating a sense of community because (1) it provides more opportunities for reflection and dialogue compared to a fast and free-flowing f2f environment; and (2) online interactions are "group centred" as opposed to "authority centred", as online interactions build on previous contributions while f2f interactions tend to take the form of turn-taking.

In terms of research collaborations, technology allows "more diverse and distant groups of scientists to communicate with each other so that their collective work is coordinated (e.g. standards are developed, data aggregated), and that some aspects of the work can be automated or enhanced (e.g., through visualization and computational aids)" (Olson, 2008, p.3). The use of technology has increased both possibilities for research collaborations and motivation to communicate with other members of their scholarly community nationally and internationally (Costa & Meadows, 2000, p. 260). Online components are now a common feature supplementing f2f professional and academic conferences, while virtual conferences enable researcher to share their findings and interact remotely (Ball, 2000). As a result, research communities have become increasingly internationalised.

New collaboration and information sharing opportunities are increasingly created through Web 2.0 applications and technologies (Boulos, Maramba and Wheeler, 2006). Social software tools, such as blogs, wiki, podcasts, trackbacks, videoblogs enable individuals and groups to create *microcontent*, "content blocks that can be saved, summarised, copied, quoted and built into projects" (Alexander, 2006). Alexander suggests that pedagogical applications of one of the key categories of Web 2.0 - social bookmarking (e.g., del.icio.us), - can be derived from their "affordance of collaborative information discovery. For instance, researchers at all levels (students, faculty, staff) can quickly set up a social bookmarking page for their personal and/or professional inquiries”. This way researchers can store, describe and categorise project related links, find people with related interests and reveal new patterns through tag clouds that may offer new perspectives on a research topic. Collaborative writing and editing opportunities are offered by Web 2.0 social writing platforms and wiki and wiki-like tools and environments. Tools like Writeboard, Socialtext, TWiki, JotSpotLive allow users to set up accounts, write and revise their collaborative work, block access to or control editing rights for selected pages. Tal-Elhasid and Meishar-Tal (2007) list the following applications of wikis in a teaching/learning environment: collaborative writing intended to improve writing skills, joint editing of coursebooks, and creation of an environment for writing collaborative assignments. Tal-Elhasid and Meishar-Tal (2007) also argue that the wiki technology allows instructors to select and apply appropriate type of assessment in cooperative and collaborative learning, because the use of wikis allows to measure individual student contributions, to assess both the quality of the final product and the collaboration processes, and to evaluate the volume of activity in terms of content, dates and users. On the other hand, the inherent openness of Web 2.0 environment may not be suitable for some types of academic collaborations, and issues may arise in terms of copyright, access to research information and access to student course work.

Technology advances have enabled new forms of distributed scientific collaborations discussed earlier – *VREs* and *collaboratories* – which “fosters contact between researchers who are both known and unknown to each other, and provides access to data sources, artifacts, and tools required to accomplish research tasks” (Bos and Zimmerman, 2007, p. 656). These environments incorporate joint access to facilities, services, information and data, made possible by the development of computer technologies, and enable researchers to interact and work together without having to share the same physical space, by taking advantage of the advanced networks, groupware, the Internet and Web 2.0 tools and applications [see Figure 3].

***Figure 3.*** *From the Science of Collaboratories (SOC) Project,* *http://www.scienceofcollaboratories.org/*




VREs (such as Sakai-based environments, see http://www.aers.or.uk/portal/) have been shown to enable collaborative research that uses the *communities of inquiry* methodology (Wilson et al., 2007, 2008). Social software techniques characteristic of Web 2.0 inform approaches to developing digital objects supporting the work of collaborating scientists, as shown in the article by De Roure & Goble (2007) which describes the creation of the *myExperiment* VRE (http://wiki.myexperiment.org).

Internet technologies are also increasingly used to support the development of online communities of practice (Smith, 2003; Wenger, 1998). Wenger (2001) writes that “an increasing number of communities of practice today are geographically distributed and must rely on some kind of technology for keeping in touch" (p. 45). In a survey of community oriented technologies, Wenger provided a list of online facilities useful to a CoP and specified three general requirements for a technological platform for CoPs: ease of use, ease of integration and low cost. Wenger suggests that technology can facilitate the following CoP practices: time and space (presence and visibility; rhythm); participation (variety of interactions; efficiency of involvement); value creation (short-term value; long-term value); connections (connection to the world); identity (personal identity; communal identity); community membership (belonging and relationships; complex boundaries); community development (evolution: maturation and integration; active community-building).

Recently, Wenger and colleagues (Wenger, White, Smith, & Rowe, 2005) continued this line of work, further researching how CoP and technologies shape each other. They report that the number of CoP has proliferated and new technologies have been incorporated into the life of these CoPs. They point out that communities are involved in "many activities that are often mediated, supported, or enhanced by technology" (p. 2).

### *4.2 Challenges*

The challenge in using technology is that participants "must be comfortable with collaboration tools that are highly customized and simply new to them" (Bender, 2004). A number of publications underscore that the process of collaboration can be substantially improved by training (Toomela, 2007, p. 201, Greene, Hart, & Wagner, 2005; Miller, 2004; Prichard, Stratford, & Bizo, 2006).

Another challenge for e-collaborations is technical difficulties and imbalances between collaborative partners. One project (Larsson et al., 2005, p. 68) where technology proved to be problematic was an online teaching collaboration between three countries and South Africa. Due to the less developed Internet network in South Africa, the other partners had to scale down their use of technology to fit with the South African University. In addition, adherence to technical standards, such as a common format for Web pages, can prove problematic, especially in cases where partner institutions have their own particular preferred formats (Rich et al., 2000).

Another interesting point is made by Borgman (2006), who suggests that good matching between technology and tasks is important, but is not the only one factor in the overall success of e-collaborations. Borgman (2006, p. 375) concludes that "[w]hile the technology juggernaut of e-Science and cyberinfrastructure suggest that better tools will result in more use and re-use of scientific data, our results indicate that the relationship between tools, use, and re-use is very complex. Making data, teaching resources, or other forms of content easier to share does not mean that scientists *will* share."

In terms of teaching with technology, Wang identifies such problems as extra time required to facilitate chat discussion, along with the difficulties some academic staff may have with technology and the lack of available time to practice using the technology (Wang, 2007, p. 286). Wang observed that despite academic staff being comfortable with using email and encouraging students to use online resources, they "hardly used chats, or recommended listservs to students, or posted students' work on web pages" (ibid).

## V. Summary and Conclusions

This paper has reviewed issues related to academic collaborations and e-collaborations pertinent to the development of our understanding of the nature of collaborative activities, especially those involving remote participation. We looked at different types of collaborations in research, teaching and learning, as well as common tasks, activities and functions associated with remote collaborations. We also considered the role of ICT technologies in supporting e-collaborations. Of course there are many important institutional, socio-economic, cultural, personal and interpersonal success factors affecting collaborative work (see for example, Maglaughlin & Sonnewald, 2005; Borden, 1992; Sgori & Saltiel, 1998). However, these factors are outside the scope of this project. The focus here is on identifying the kinds of processes that take place in successful e-collaborations and the kinds of technologies that are able to support these processes.

Despite the differences between the culture and goals of e-collaborations in research and in teaching and learning discussed in this paper, each of these collaborative practices can benefit from the other's strong points, i.e., e-learning practitioners often being more open towards the adoption of new emerging ICT and Web 2.0 technologies than e-researchers, while e-researchers leading the way in terms of utilisation of the network capabilities in instrument sharing and data gathering, storing and sharing. Furthermore, both e-research and e-learning collaborations could benefit from studying ways in which distributed communities that share a common interest or practice function in Cyberspace.

Although the review highlights the complexity of the collaborative enterprise, in particular when it takes place remotely, there is a clear consensus in the literature that collaborative activity, both in research and in teaching and learning, holds significant benefits and will continue to grow. The literature suggests that in undertaking e-collaborations it is important to consider such parameters as the *purpose of collaboration*, *field/s of study*, *participants*, *location*, *duration* and *scale*. The processes and functions associated with collaborations can be roughly grouped into 1) *coordination, administration, project management, leadership*; 2) *production (creating new knowledge and understanding)*; 3) *content and data management*; and 4) *communication and interaction*. Accordingly, environments and tools developed or selected for collaborations need to be able to support these processes and functions. This does not imply linear one-to-one tool-function relationships, however, since one tool may be used in different ways to support a range of functions, and vice versa, one process or function may require the use of a number of individual tools.

Based on the results of this review, a questionnaire has been developed to gather data about collaborative projects and activities taking place in the New Zealand[1] tertiary sector (see Appendix 2). This data will be used to fine-tune the development of an e-collaboration guide to assist teaching and research staff, as well as students participating in collaborative learning activities, in operationalising the core functions and activities that need to take place in the course of e-collaborations and choosing technologies to support them.

[1] In the future, data collection may be extended to include academic collaborations outside New Zealand.

## Appendix 1

### *Success Factors in Collaboratories. Olson (2008)*

1. The Nature of the Work

- Participants can work somewhat independently from one another
- The work is unambiguous

2. Common Ground

- Previous collaboration with these people was successful
- Participants share a common vocabulary
- If not, there is a dictionary
- Participants share a common management or working style

3. Collaboration Readiness

- The culture is naturally collaborative
- The goals are aligned in each sub-community
- Participants have a motivation to work together that includes mix of skills required, greater productivity, they like working together, there is something in it for everyone, NOT a mandate from the funder, the only way to get the money, asymmetries in value, etc.
- Participants trust each other to be reliable, produce with high quality and have their best interests at heart
- Participants have a sense of collective efficacy (able to complete tasks in spite of barriers)

4. Management, Planning and Decision Making

- The principals have time to do this work
- The distributed players can communicate with each other in real time more than 4 hours a day
- There is critical mass at each location
- There is a point person at each location
- A management plan is in place
- The project manager is respected has real PM experience exhibits strong leadership qualities
- A communication plan is in place
- The plan has room for reflection and redirection
- No legal issues remain (e.g. IP)
- No financial issues remain (e.g. money is distributed to fit the work, not politics)
- A knowledge management system is in place
- Decision-making is free of favoritism
- Decisions are based on fair and open criteria
- Everyone has an opportunity to influence or challenge decisions
- Leadership sets culture, management plan and makes the collaboratory visible.

5. Technology Readiness

- Collaboration technologies provide the right functionality and are easy to use
- If technologies need to be built, user-centered practices are in place
- Participants are comfortable with the collaboration technologies
- Technologies give benefit to the participants
- Technologies are reliable
- Agreement exists among participants as to what platform to use
- Networking supports the work that needs to be done
- Technical support resides at each location
- An overall technical coordinator is in place

Special issues:

- If data sharing is one of the goals, defacto standards are in place and shared by all participants, and a plan for archiving is in place
- If instrument sharing is part of the collaboration, a plan to certify remote users is in place.

## Appendix 2

### QUESTIONNAIRE: e-Collaboration in Learning, Teaching and Research

**Part 1: Overview**

1. Title of collaboration
2. Brief description of collaboration
3. Primary field of collaboration [research/development; teaching/learning; other]
4. Purposes/Goals of collaboration [co-authorship; joint data collection; joint development of resources (including teaching resources); joint use of technology (tools, instruments); carrying out a research project (new knowledge, new findings); sharing information; joint delivery of courses; learning about other disciplines and approaches; learning activity as part of a course of study; other]
5. Participants [academic staff; research staff; teaching staff; library staff; corporate; professional organisations; corporate organisations; undergraduate students; graduate students; community groups; other]
6. Would you describe your collaboration as [peer-similar (e.g., between students, between staff); peer-different (e.g., teacher / student or apprentice; lead researcher / support or assistant researchers)]
7. Duration of collaboration [short term; medium term: long term, ongoing (e.g., community of practice)]
8. Geographical location of participants [co-located; remote or distant]
9. Organisational location of participants [same department / unit of the same university or organisation; different departments / units of the same university or organisation; different universities or organisations]
10. Scale of collaboration [one-to-one or a small group; group-to-group; whole unit/organisation; across organisations; community of interest or community of practice; other]
11. Would you describe your collaboration as [formal; informal]
12. Would you describe your collaboration as [direct; indirect or serial]
13. Would you describe your collaboration as [unidirectional; dialogical]
14. Would you describe your collaboration as multidisciplinary?

**Part 2. Processes and Functions** (*In what collaborative processes and functionalities did you engage? <u>Select all applicable</u>.*)

1. *Coordination, administration, project management, leadership* [processes integration (*division of labour into tasks, managing dependencies, coordination of tasks to accomplish the overall activity*); organising interactions, meetings, events; coordinating distributed activities; monitoring and motivating contributions; conflict resolution; guidance by a team leader; providing technical support; management and distribution of information; managing access and security; managing intellectual property; managing users (memberships and roles); other (specify)]
2. *Production (Creating new knowledge and understanding)* [designing a research or development project; selecting and applying methodology; generating and/or collecting data; creating resources and artifacts; modelling, simulating and visualizing; experimenting and testing; analysing and evaluating; writing, editing, authoring (collaboratively); sharing document; sharing instruments; sharing applications; brainstorming; controlling quality; other]
3. *Content and data management* [capturing and authoring documents and data; storing and managing documents, data and outputs; versioning and archiving; publishing of information and data; searching and retrieving documents and data; developing/applying data and meta-data standards; other]
4. *Communications and Interaction* [decision making (*analysing and evaluating alternatives; making choices*); structured deliberation; discussion (synchronous and asynchronous), including challenging contributions of others, negotiating and resolving conflicts; exchanging information; presenting and demonstrating; seeking, giving and receiving help, advice and feedback; instructing; negotiating; documenting / reflecting (*journaling*); reporting; other]
5. In your opinion, to what degree was this collaboration successful?
6. List factors that, in your opinion, contributed the most to the success of your collaboration.
7. List factors that, in your opinion, were the biggest obstacles in your collaboration.

**Part 3. Use of Technology**

1. Did you use technology in your collaboration?
2. We used technology

- for synchronous (same time) communication and interaction (e.g., chat, online meetings, discussions, conferences, etc.)
- for asynchronous (delayed) communication and interaction (e.g., bulletin boards, threaded discussions, etc.)

- to perform the core collaboration or project tasks (*collaborative research, teaching or learning activities, e.g., co-authoring publications; collecting or generating data; performing analysis or evaluation; creating resources and artefacts*; *categorising, organising and presenting information*)
- to store, manage and retrieve content (information, resources and data)
- to coordinate and manage collaborative tasks (coordination, administration, project management, leadership activities)
- other

-1. 3. If you were to participate in a similar collaboration again, for what further activities / tasks would you have liked to use technology?

-1.

**Part 4: Tools and Environments**

This collaboration used … (*tick all applicable and* *specify the tools/products used*, *if possible*)

- a purpose-built collaborative environment
- a commercial (proprietary) platform
- an open-source environment
- a content management system
- a course (learning) management system
- specialised instruments, equipment, shared remotely
- visualisation and/or modelling tools
- a shared document repository
- a shared data repository
- a web page / web site
- synchronous communication tools (e.g., chat, instant messaging, online conferencing) [text based; multimedia]
- asynchronous communication tools (e.g., e-mail, discussion boards, online forums,) [text based; multimedia]
- collaborative writing/editing tools
- collaborative presentation tools
- sharing desktop, applications, software tools
- collaborative project management tools (e.g., shared calendar, meeting booking system, task management and work flow tools)
- search tools
- decision making tools (e.g., voting tools)
- blogging or online journaling tools
- web publishing or wiki tools
- aggregation and notification tools (e.g., RSS feeds)
- social bookmarking / tagging tools
- other

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